Can Heat Pump Water Heaters Teach the California Duck to Fly?

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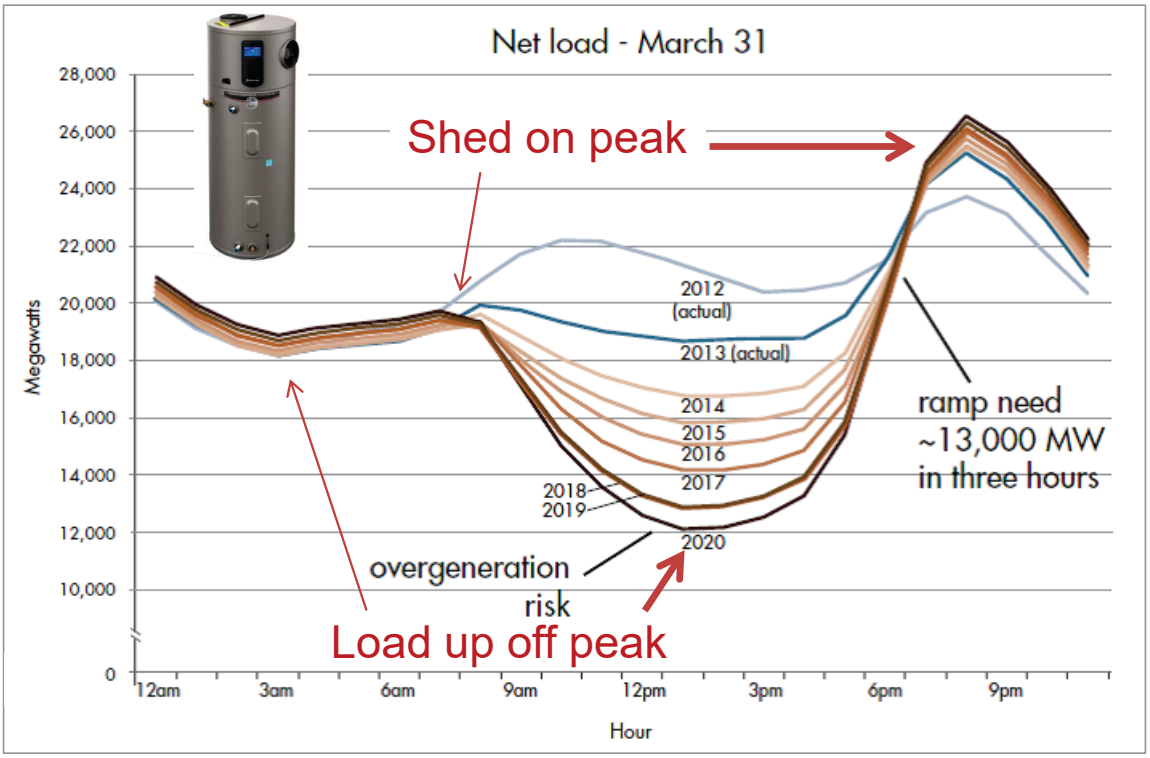
Study objective: Assess heat pump water heater demand flexibility potential in California



Study approach

Simulation

- Ecotope simulation model

- ✓ NEEA-validated
- ✓ Integrated in CA Title 24

Lab testing

- 4 HPWH models
- Calibrate Ecotope's model
- Validate simulation results

Rheem 50-gal 	AO Smith 66-gal 
Bradford-White 80-gal 	Sanden 83-gal 

NRDC

PG&E 2024 Hourly Marginal Costs

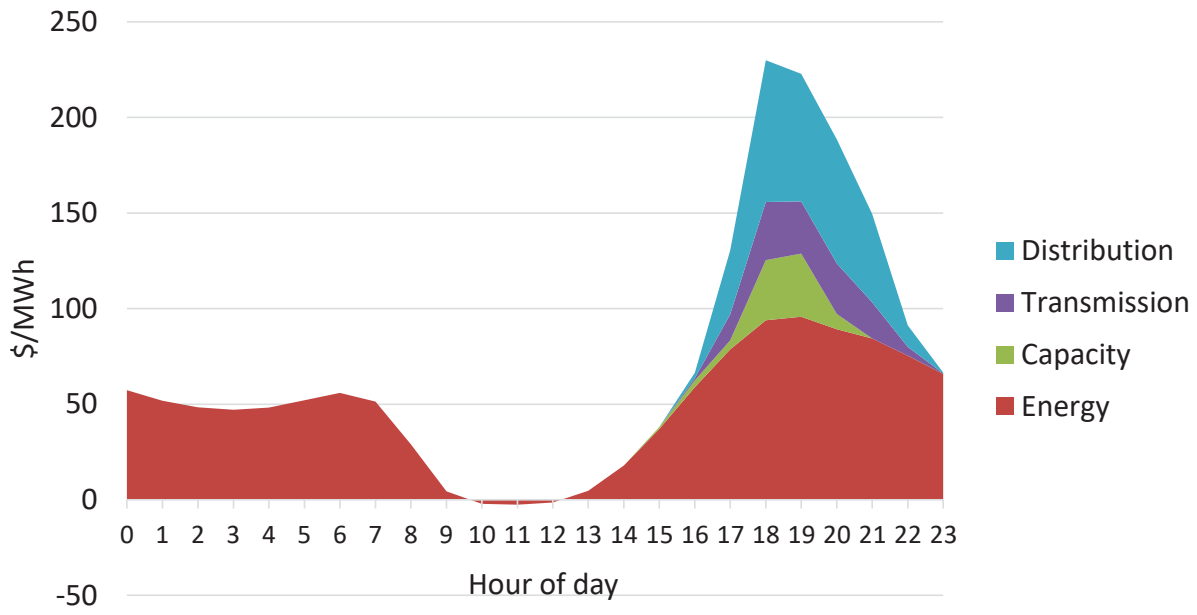
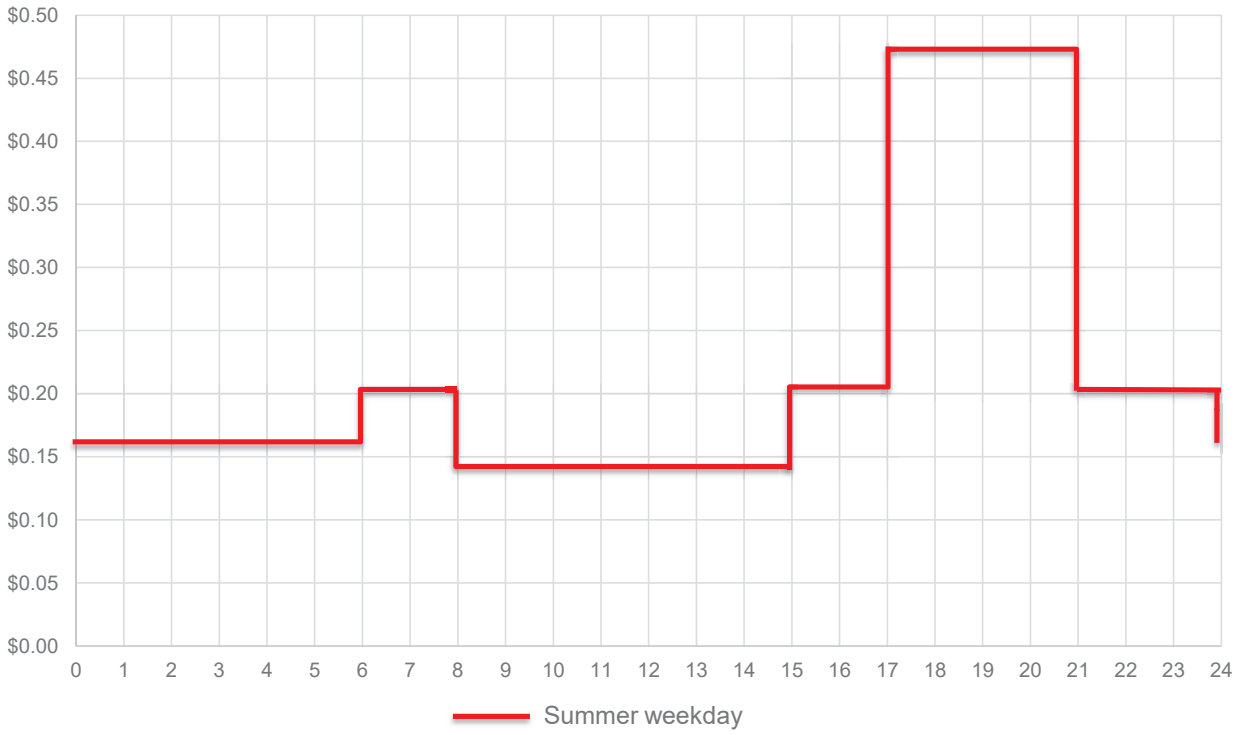


Chart shows annual average of hourly values for simplicity. Study has hourly values for entire year.

Time of Use rate: designed by NRDC for this study



Control Strategies: How to optimize HPWH operation for price schedules

3 levels of control “smartness”:

1) **Simplest**: On/off timer

2) **Smarter**: Smart load-up / soft shed

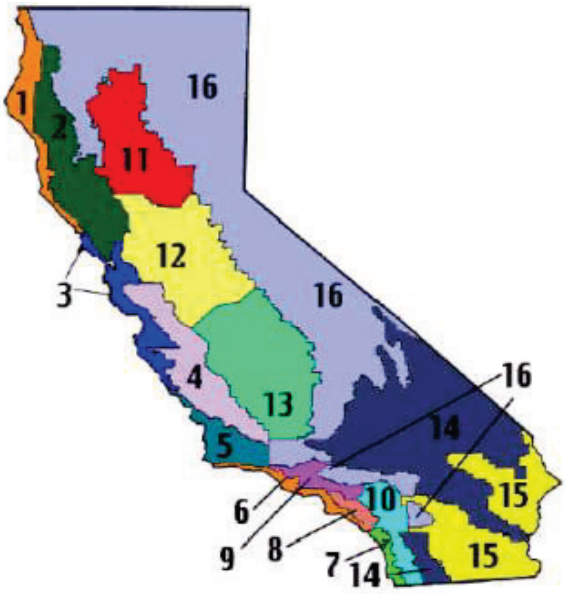
3) **Smartest**: Hourly price optimization, grid-connected

Simulation Runs

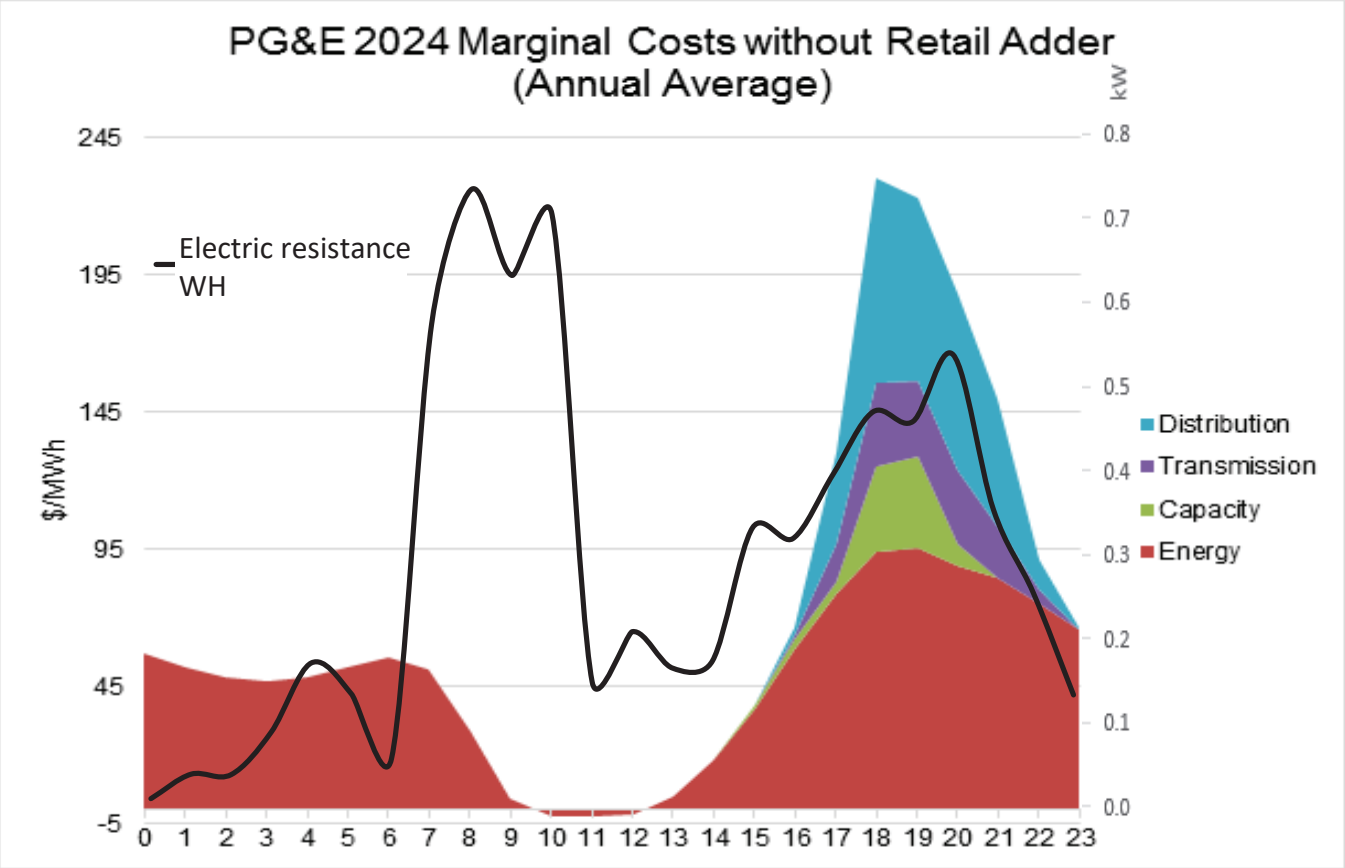
Parameters:

Input values	# values
Price signals • Utility marginal costs • Customer time of use • CEC Time Dependent Valuation	3
Units • Hybrid HPWH, HP-only, ERWH • 50, 65, 80 gallons	11
Max water temp: 125, 135, 145, 155	4
Climate zones: 16 CA climate zones	16
Draw patterns: 1-5 bedrooms	5
Control strategies • On/off timer • Smart load-up / soft shed • Optimal price	3
Total Scenarios	**31,680**

California climate zones:



Sample results
CZ12*, 3 bedrooms, 50G ERWH, 66G HPWH



* CA climate zone 12: Sacramento

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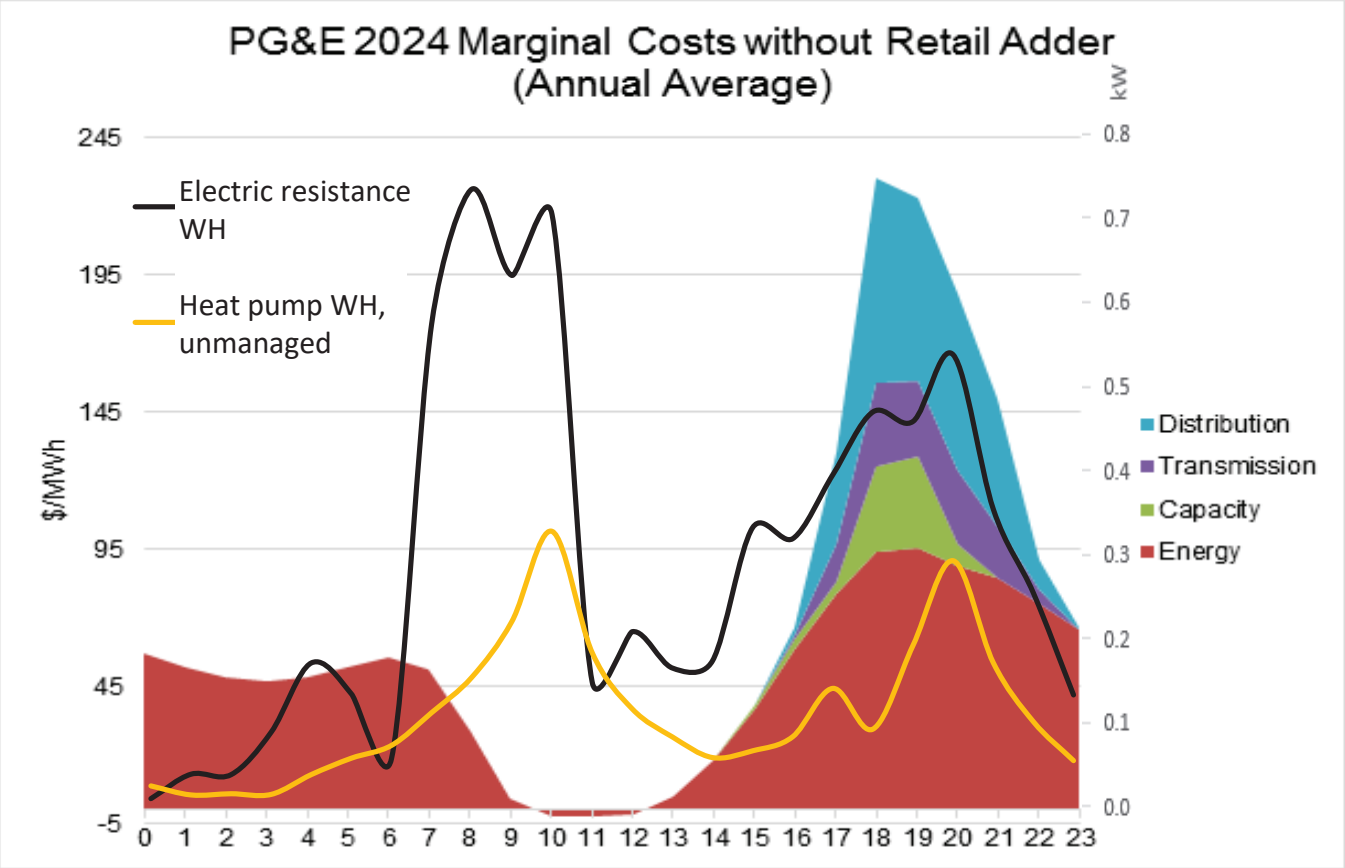

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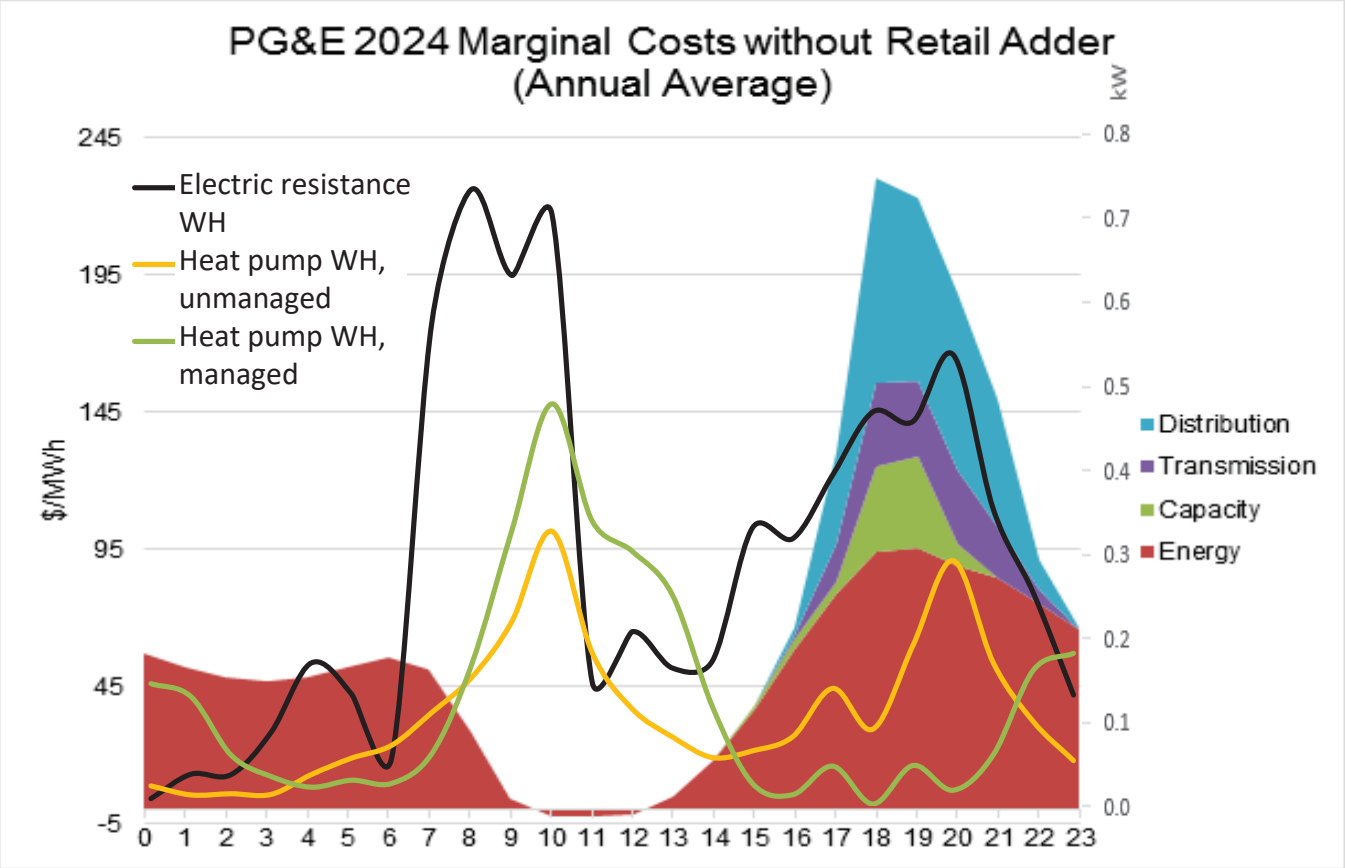

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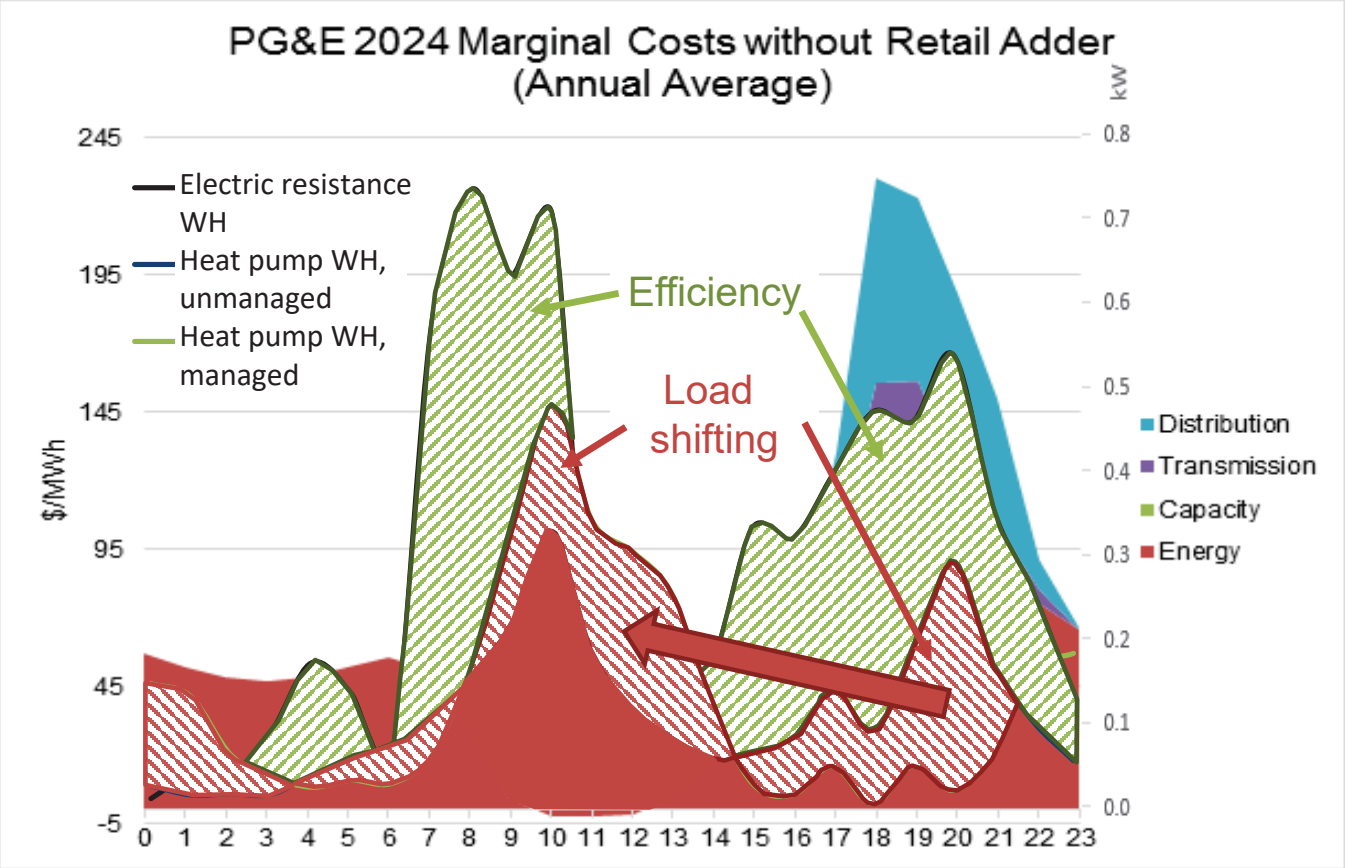

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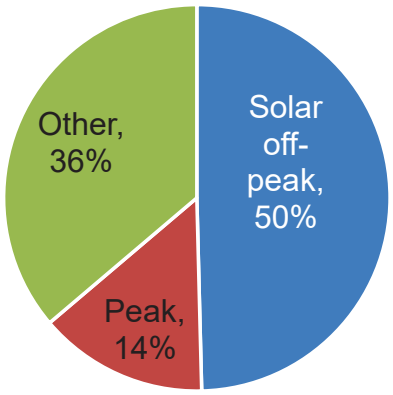
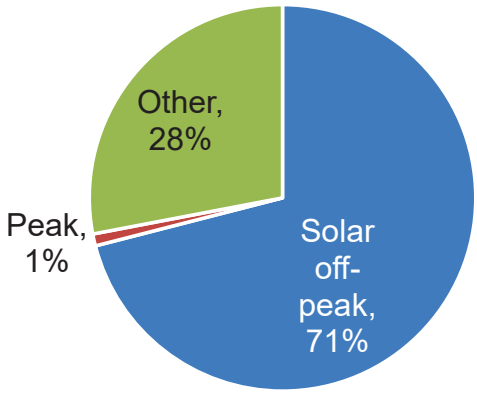
Peak demand coincidence

HPWH Unmanaged



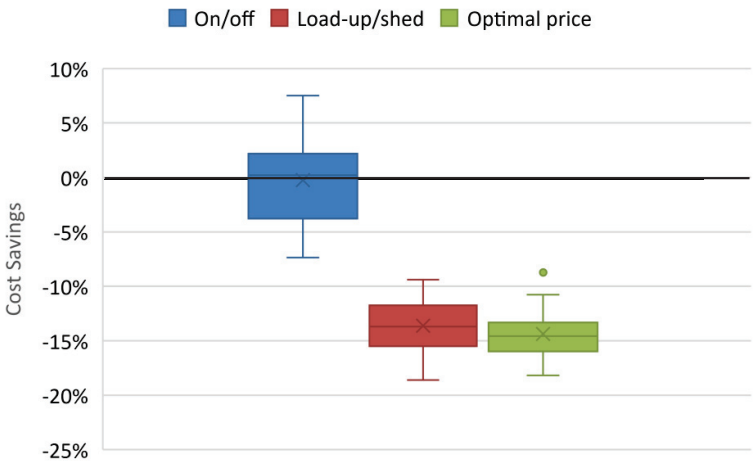
HPWH Managed



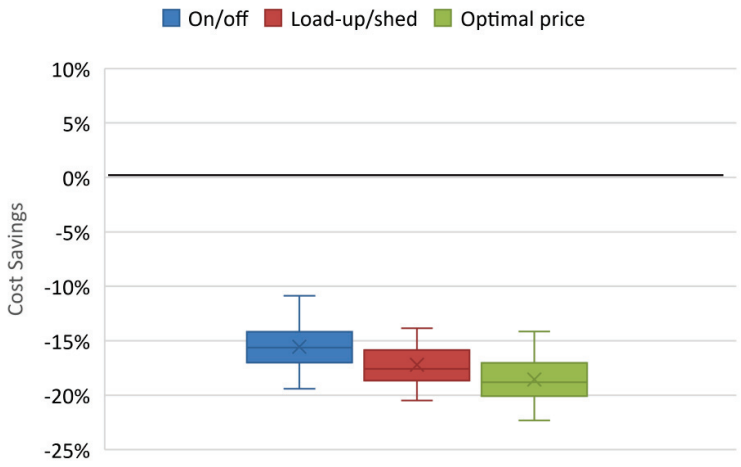
Off-Peak Solar: 8 am – 3 pm
Peak: 5 pm – 9 pm

Cost Savings by Control Strategies

Hybrid (R134a)*



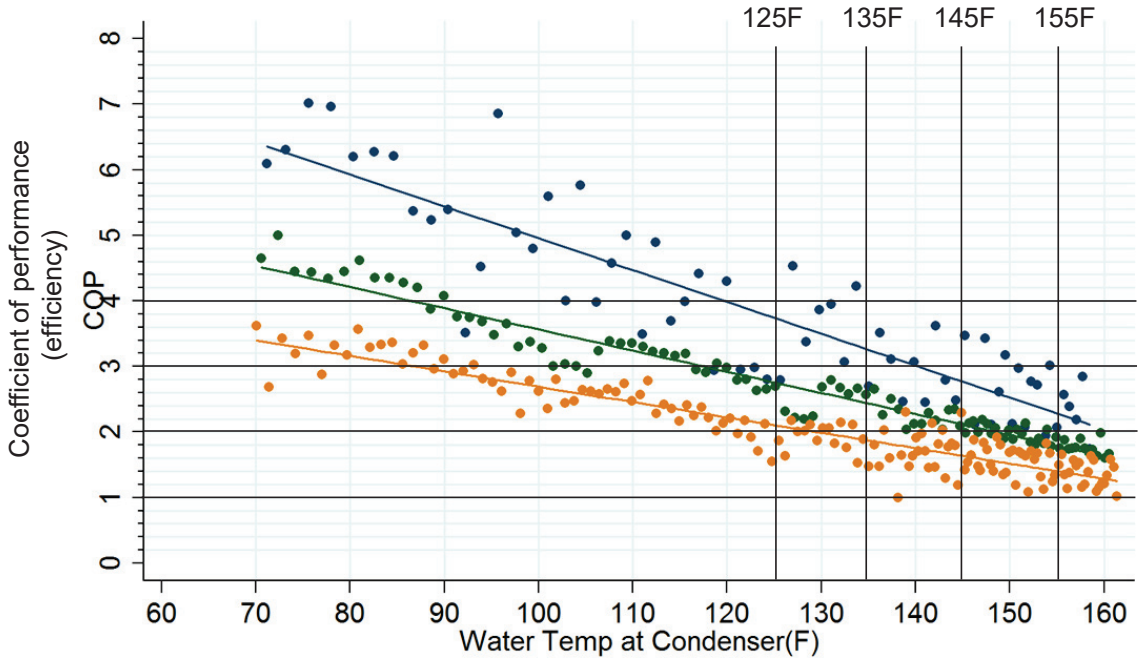
Heat Pump-only (CO2)



* Hybrid HPWH with 135F load-up set point

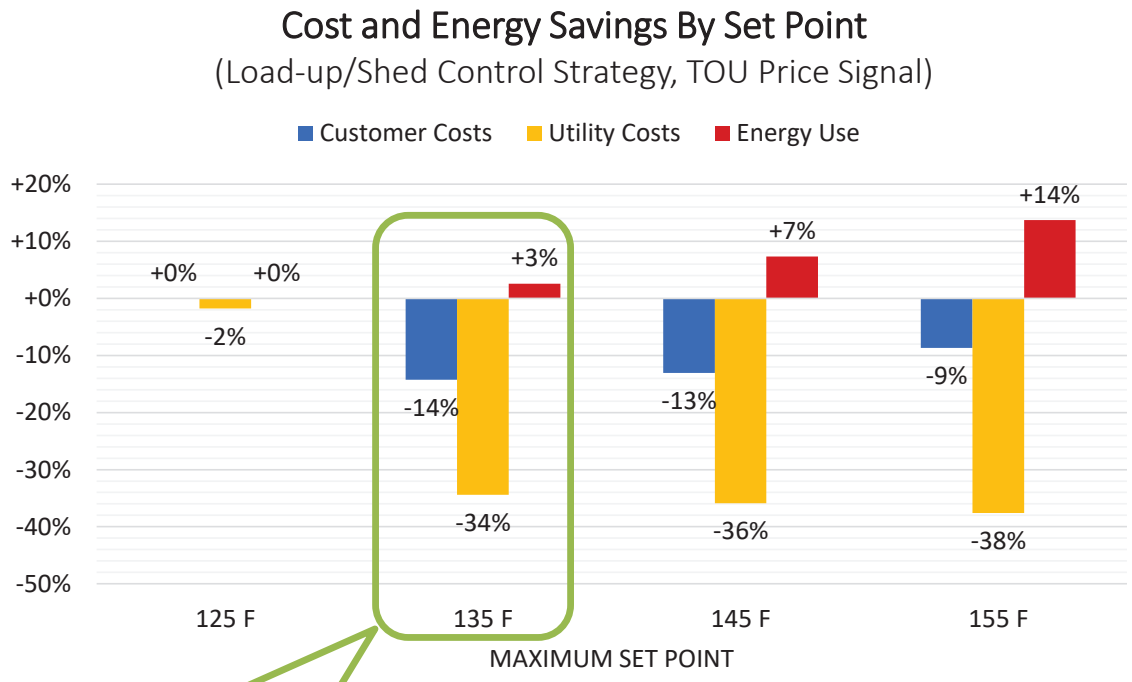
Lab testing results: Compressor efficiency decreases as set point increases

Measured compressor efficiency at higher water temperatures:



Air Temperature: Blue – 95F, Green – 67.5F, Gold – 50F

Optimal Control Temperature



Operational costs savings

Operational savings depend on what controls optimize for:

	Customer bill savings	Utility marginal cost savings
Optimizing for customer costs (TOU)	-15% to -20%	-35%
Optimizing for grid marginal costs	0% to +5%	-60%

Outcomes scorecard*

	ERWH Unmanaged	ERWH Managed	HPWH Unmanaged	HPWH Managed
Effective storage capacity / evening	-	1.3-1.8 kWh	-	0.5-0.6 kWh
Energy use (kWh/y)	2,570	2,640 (+3%)	1,070 (-58%)	1,090 (-57% / +2%)
Resistive kWh	100%	100%	16%	14%
Consumer bills	$500	$380 (-25%)	$190 (-60%)	$160 (-70% / -15%)
Utility marginal costs	$180	$80 (-55%)	$60 (-70%)	$40 (-80% / -35%)

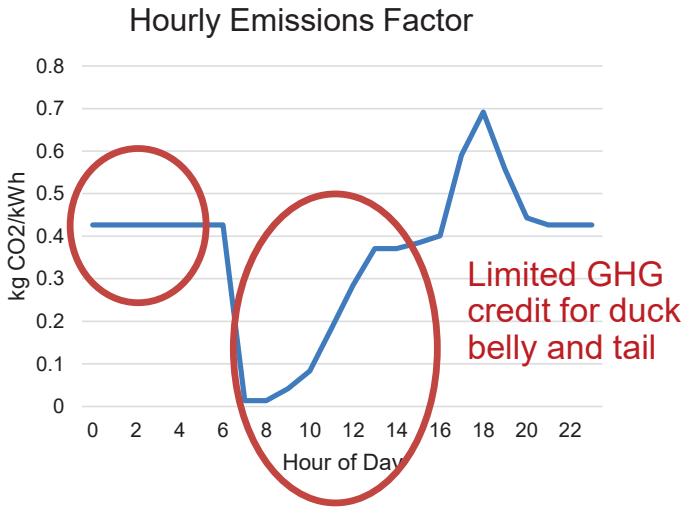
* 3-bedroom house, CZ12 (Sacramento)
ERWH 50-gallon + 30F thermal storage
HPWH 65-gallon +10F thermal storage

How about GHGs?

	ERWH Unmanaged	ERWH Managed	HPWH Unmanaged	HPWH Managed
CO2e (kg)	684	497 (-27%)	275 (-60%)	229 (-66% / -16%)

Wait, why not higher GHG reductions from load management?

- GHG accounting methodology issue:
  - ACM* gives limited credit for mid-day load
  - Uses dispatch, not build marginal accounting
  - Does not appropriately value load shifting
- HPWH load management would yield much higher GHG benefits under build marginal methodology



* CPUC Avoided Cost Model 2018: http://www.cpuc.ca.gov/General.aspx?id=5267

Key Takeaways

Significant potential for cost-effective HPWH load shifting

1. Can shift virtually all of evening load to middle of day
2. 130-140 F load-up temperature “sweet range”
3. 15-20% customer savings potential
4. 30-60% utility savings potential

Requires:

1. Smart control technology
2. Customer compensation mechanisms: TOU rates and/or bill credits
3. Incentive programs and supportive regulations (e.g. building code)
4. Appropriate GHG accounting methodology for load shifting